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MARSHALLIAN VS. WALRASIAN STABILITY IN AN EXPERIMENTAL MARKET

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ABSTRACT

Twelve markets were studied. All markets had downward sloping supply functions created by Marshallian-type external economics. The conditions were such that the Marshallian theory of dynamics gave predictions opposite to the Walrasian theory of dynamics. The market organizations studied were double auction, sealed bid/offer and (secant) tâtonnement. In all cases the Marshallian theory of dynamics was the better model.

MARSHALLIAN VS. WALRASIAN STABILITY IN AN EXPERIMENTAL MARKET*

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I. INTRODUCTION

The experiments discussed below are an attempt to examine concepts of stability as found in economics textbooks. Two concepts of stability, which stem from two different concepts of market adjustment, seem to have dominated thinking. One was advanced by Walras and the other by Marshall. Since these two concepts lead to competing hypotheses about the conditions under which market instability will be observed, the subject is a natural one for experimental investigation. Furthermore, since this is the first experimental examination of the stability of equilibria, the strategy is to inquire about stability in the context of these two classical models and to avoid the temptation to attempt to extend them or integrate them with more modern theory. The old models have not been checked. They seem to be an appropriate place to start.

The Walrasian model views price as changing in response to excess demand at that price. The Marshallian model views volume as adjusting in response to the difference between demand price and supply price at that volume. These two models hold different implications for general theories of disequilibrium and market adjustment, and they make different statements about the conditions under which markets will exhibit instability. If supply is negatively sloped and if demand cuts supply from above, then the equilibrium is Walrasian unstable and Marshallian stable. If supply is negatively sloped and if demand cuts supply from below, then the equilibrium is Walrasian stable and Marshallian unstable. In Figure 1 the downward sloping supply function is the curve SS. Given the demand function $D_1 D_1 D_1$, three equilibria exist excluding the boundaries. Points c and e are Walrasian unstable and Marshallian stable. Point d is Walrasian stable and Marshallian unstable. The vertical boundary contains an additional stable Walrasian (but not Marshallian) equilibrium and the horizontal boundary contains an additional stable Walrasian (but not Marshallian) equilibrium. If the demand function is $D_2 D_2 D_2$, point c is Walrasian (Marshallian) stable (unstable) and point d is Walrasian (Marshallian) unstable (stable). Point e is no longer an equilibrium. The vertical axis contains a Marshallian (but not Walrasian) stable equilibrium and the horizontal axis contains a Walrasian (but not Marshallian) stable equilibrium.

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This project was first assigned as a project in an experimental economics class. Stephen Pitts contributed significantly to the development of instructions and to finding parameters of the continuous model that yielded acceptable integer solutions. The comments of John Ledyard and Jeffrey Dubin influenced the experimental design and data analysis. Comments by Gary Becker and Eskander Alvi were useful in helping us understand the theories and the literature. Special thanks go to Jessica Goodfellow for her help as a research assistant.

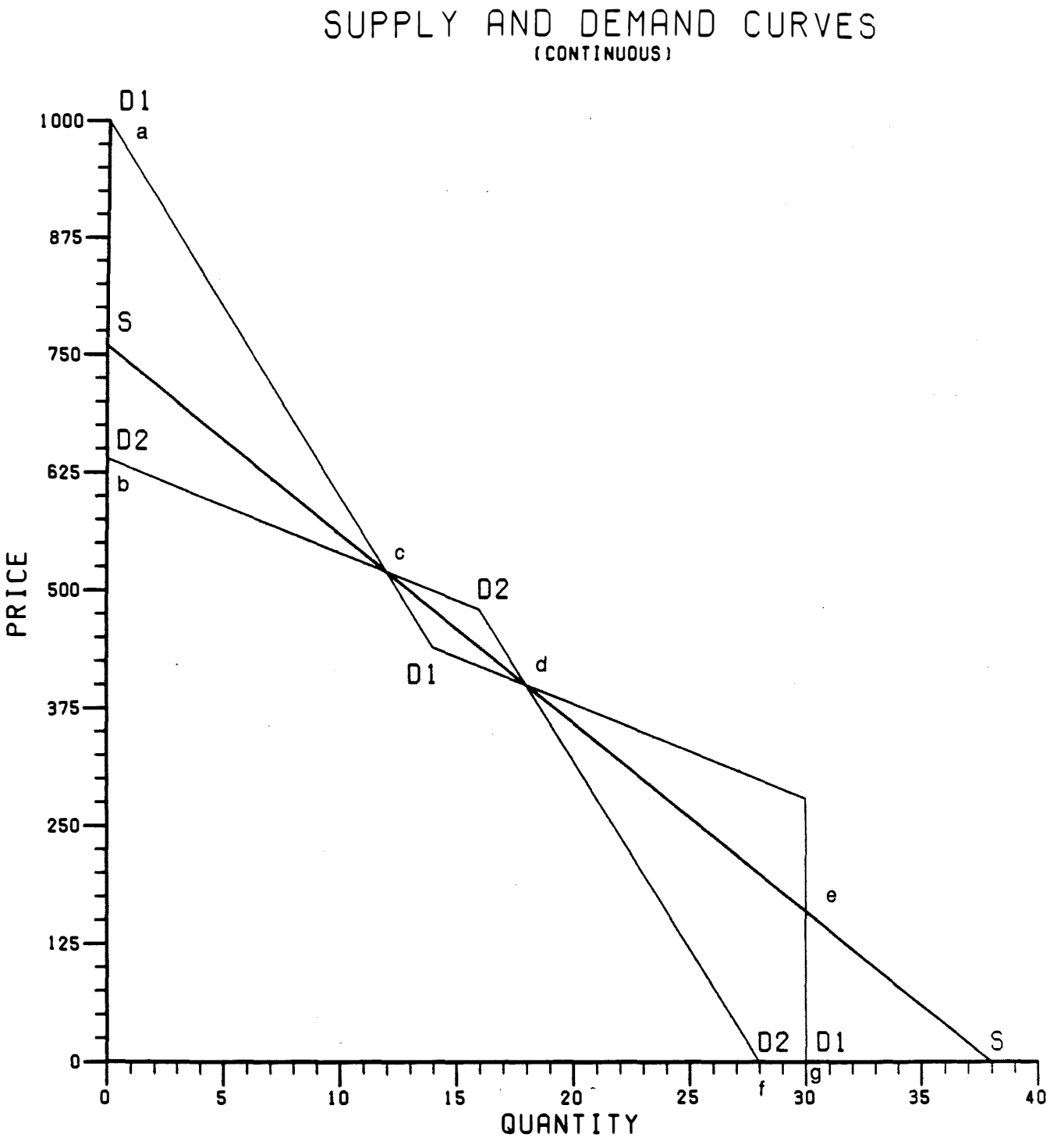
SUPPLY AND DEMAND CURVES
(CONTINUOUS)
D1
a
1000
875
S
750
D2
625
b
c
D2
500
D1
d
375
250
e
125
D2
D1
S
0
f
g
0
5
10
15
20
25
30
35
40
PRICE
QUANTITY

FIGURE 1

The curves in Figure 1 are continuous approximations of the parameters actually used in the experimental markets. Presumably only the stable equilibria can be observed. The markets first exist under conditions D_1 and according to theory the emerging prices should be near to one of the stable equilibria. If demand is then shifted to D_2, then prices and volume should move to one of the other equilibria because every stable equilibrium under D_1 is unstable under D_2. This relationship among the equilibria is the key to the experiments reported in the paper.

Two major problems present themselves to anyone who attempts to conduct experiments on these models. The first and most difficult is determining a method for experimentally inducing a negatively sloped supply. The markets created for this study all have "forward falling" as opposed to "backward bending" supply curves. The second problem involves a choice of market institutions. Three different market organizations are studied: the double auction, the sealed bid/offer, and the secant tâtonnement.

Three basic questions are posed by the research. The first deals with the applicability of the law of supply and demand. If the downward sloping supply curve is forward falling, it is not obvious that the textbook concept of equilibrium (the intersection of demand and supply) applies. The supply curve involves elements of consistent expectations. Furthermore, allocations and prices that are equilibria under the definition that market demand equals market supply might not satisfy the definition of equilibria in game theoretic models of the same environment. The question is: does the market demand and supply model predict price and volume? The second question is: does either concept of stability have predictive power? It is not obvious that these classical notions of stability, which originated by analogy to physical phenomena (Walras 1954, p. 112; Guillaband 1961, p. 346), have any predictive power at all in a market context. The third question asks which stability concept is more appropriate. The final question is an inquiry about the sensitivity of answers to all of the above questions to market organization. Certainly the usual description about Marshallian vs. Walrasian stability leans heavily on the existence of a price taking process such as tâtonnement. Does the relevance of a stability concept depend upon how the market is organized?

II. PARAMETERS

The market demand and market supply functions based upon the actual parameters used in the experiment are shown in Figure 2. Subjects were primarily undergraduate students and graduate students from the California Institute of Technology. Preferences and costs were established by application of standard financial inducement techniques (see Plott 1982 or Smith 1982). The actual instructions are included as an appendix.

A. *The Demand Curve*

Six agents were designated as demanders. These demanders were partitioned into two demanders of each of three types. The redemption values are in Table 1. Buyers were given two tables. One contained their marginal redemption values for all periods, and the other contained totals.

Two different aggregate demands were used. These are labeled condition D_1 and condition D_2 as shown in Figure 2. In most experiments a shift of demand occurred in period 10. The first ten periods were under condition D_1 and then the demand was shifted to D_2. However, in some

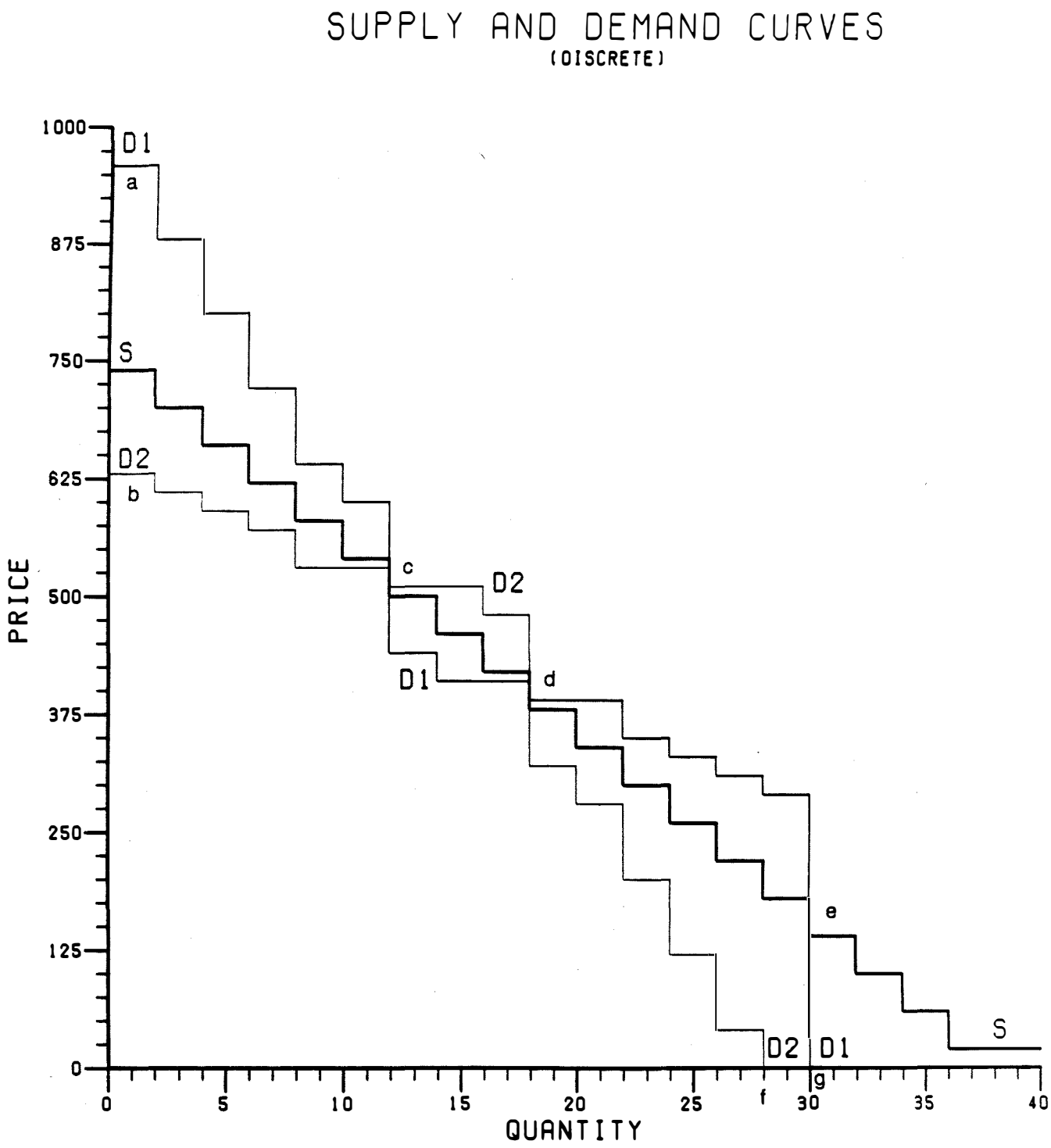
SUPPLY AND DEMAND CURVES
(DISCRETE)
PRICE
QUANTITY
1000
875
750
625
500
375
250
125
0
0
5
10
15
20
25
30
35
40
D1
a
S
D2
b
c
D2
D1
d
e
S
D2
D1
f
g

FIGURE 2

TABLE 1

Redemption Value Table for Demanders

	Condition D_1			Condition D_2		
	Agent			Agent		
Unit	1 & 6	2 & 5	3 & 4	1 & 6	2 & 5	3 & 4
1st	960	880	800	590	610	630
2nd	600	640	720	570	530	530
3rd	440	410	410	480	510	510
4th	350	390	390	200	280	320
5th	330	310	290	120	40	0
6th	0	0	0	0	0	0

experiments conditions D_1 were maintained longer than ten periods to see if convergence to a theoretical equilibrium would become "closer" with more periods under the same demand conditions.

B. *The Supply Curve*

The literature discusses three forms of negatively sloped supply. The "backward bending" curve is usually associated with "backward bending" individual supplies derived from negative income effects. The backward bending labor supplies are the typical example. The second form is the "forward falling" supply curve associated with the existence of an externality. According to the forward falling concept, specialization in resource functions and resource supplies has the effect of lowering costs as an industry grows. Competition is maintained in the forward falling case because individual firms have upward sloping marginal costs, given the volume of others. Lowered costs are translated to lower prices through competition. The third form of negative sloped supply involves falling average cost at the individual firm level. This latter case theoretically results in monopoly.

Our choice was to study the second form. The first, backward bending, necessitated the existence of at least two commodities. Conceptually, the appropriate two commodities could be created in a laboratory setting but practical problems associated with experimental methodology precluded an immediate examination of this case. The third form is interesting and has received some attention experimentally. The monopoly case, however, is not in the full spirit of the Marshallian vs. Walrasian stability issue. Our decision was to study the second "forward falling" form.

The forward falling supply curve is usually attributed to "external economies" of scale. As *market* volume increases, the cost to each firm decreases even though an individual firm's cost increases with an increase in its own volume (volume of other firms held constant). Technically speaking, this is an externality in the cost function of each firm. That is, a firm's costs depend upon its own output and the output of all other firms.

In general, each firm has a cost function of the form $C^i(X_i, \sum_{j \neq i} X_j)$. The cost function of firm i depends upon its own output, X_i, and the output of all other firms, $\sum_{j \neq i} X_j$. The latter is the key externality.

The theory of competitive behavior yields an individual supplier's behavioral equation of the form.

$$P = \frac{\partial C(X_i, q_i^e)}{\partial X_i} \tag{1}$$

where P = market price

q_i^e = individual i's expectation about the quantity sold by others; i.e., $\sum_{j \neq i} X_j$.

Application of the theory of competitive supply yields an individual supply function of the form

$$X_i = s^i(P, q_i^e). \tag{2}$$

The theory of consistent conjectures yields

$$q_i^e = \sum_{j \neq i} X_j \quad \text{for } all \ i \tag{3}$$

at equilibrium.

Together the theory of competitive market supply gives a summation of eq. (2), and substitution from eq. (3) yields a market supply function

$$X_s = s(P). \tag{4}$$

The continuous approximations of the actual parameters used in the experimental markets will make the model precise. Let α_i be parameters specific to seller i. By assumption β and γ are parameters common to all sellers. The cost function of each firm is given by:

$$C^i(X_i, \sum_{j \neq i} X_j) = \frac{1}{2}\left[\frac{1-\gamma}{\beta}\right] X_i^2 - \left[\frac{\alpha_i - \gamma \sum_{j \neq i} X_j}{\beta}\right] X_i. \tag{5}$$

The data were given to subjects in total cost tables which were evaluations of eq. (5) and also in the form of marginal cost tables which were evaluations of

$$\frac{\partial C^i(\cdot,\cdot)}{\partial X_i} = \left[\frac{1-\gamma}{\beta}\right] X_i - \left[\frac{\alpha_i - \gamma \sum_{j \neq i} X_j}{\beta}\right]. \tag{6}$$

The actual tables seen by subjects are included as an appendix. Of course, each subject was informed of only his (her) own parameters. By applying consistent conjectures (3) and from (6), individual supply functions are characterized by the relation

$$X_i = \left[\frac{1}{1-\gamma}\right](\alpha_i + \beta P + \gamma \sum_{j \neq i} X_j). \tag{7}$$

Aggregate supply satisfies the relation

$$X_s = \sum_i X_i = \sum_i \left[\left(\frac{1}{1-\gamma}\right)\left(\alpha_i + \beta P + \gamma \sum_{j \neq i} X_j\right)\right] \tag{8}$$

which reduces to the supply function where X_s is the market supply quantity

$$X_s = \left[\frac{1}{1-n\gamma}\right]\left[\sum_i \alpha_i + Pn\beta\right]. \tag{9}$$

The objective of having a negatively sloped supply curve places some obvious parametric restrictions on (9). In particular we chose

$$\beta = y\gamma \quad so \quad y > 1 \Rightarrow \frac{\partial X_i}{\partial P} > \frac{\partial X_i}{\partial X_j} \quad \forall j \neq i$$

$$\beta > 0, \ \sum_i \alpha_i < 0 .$$

Under the above assumption the aggregate supply function is of the general form

$$X_s = \frac{\sum_i \alpha_i}{1 - n\gamma} + \frac{y\, n\gamma P}{1 - n\gamma} . \tag{10}$$

The actual parameters chosen for the supply function were

$$n = 6$$
$$y = 6$$
$$\gamma = \frac{1}{3}$$
$$\alpha_a = -6\frac{2}{3}, \alpha_b = -6\frac{1}{3}, \alpha_c = -6.$$

The indexes a, b, c, can be recognized as seller "types." Each seller of a given type had identical cost parameters. For all experiments there were two sellers of each given type (e.g., two sellers had parameters α_a, etc.). A graph of this continuous approximation is in Figure 1 and the actual parameters are in Figure 2 as the curve SS. The equation with a 240 scaling factor for P is $X_s = 38 - 1/20\, P$.

III. MARKET ORGANIZATION

While the stability notions themselves require no qualifications regarding market organization, much recent experimental work leaves no doubt that market organization is potentially important. The stability ideas themselves give hints about the form of organization that might favor one theory over the other. The Walrasian stability concept, for example, would seem to be most appropriate when a tâtonnement process is used.

Three different organizations were studied. The first is the double auction. In this process buyers tender bids and sellers tender asks publicly. Trading is open for a limited period of time[1] with a large number of potential bids and asks possible. One important feature of this organization is that market volume; i.e., the volume of others, is observed during a period. Participants are able to

1. This is true for the computerized MUDA of experiment 4 but not for the first three experiments. In the single unit oral auction, trading within the final fifteen seconds automatically added thirty seconds to the clock. In the single unit case the variable-length period was thought to be necessary to avoid biasing the results toward one of the equilibria. If the time period was short, the bias could be in favor of a small volume equilibrium. If it was long, a large volume equilibrium might be favored as individuals trade to avoid boredom, attempt to collude, etc., in the extra time. The feature was unnecessary in the MUDA because of the speed at which volume can move.

make decisions during a period contingent upon the volume that has already occurred in that period. Sellers also know that their own volume will affect the costs of others in ways that might induce others to sell more. Thus, from a practical point of view the double auction has potentially important features.

The second organization studied was a sealed bid/offer market (see Smith et al. 1982). Buyers and sellers each list the prices at which they wish to buy or sell each unit. That is, each participant submits a demand or supply function. These functions are aggregated in the ordinary way and the equilibrium is computed. The last accepted and first excluded demand and supply units determine the price. The market price is computed to be midway between the minimum of the last accepted bid and first rejected offer and the maximum of the last accepted offer and first rejected bid.

The second organization is interesting for two reasons. First, because of the "excluded price auction" feature, demand revealing aspects exist, though this is not to imply that this mechanism is demand revealing.[2] Second, a special case of the sealed offer institution is that in which suppliers bring a fixed quantity to the market which they will sell whatever the price. In any case, suppliers cannot make their offers contingent upon the actions of others in these markets so one might expect the stability if not the equilibrating properties of this process to differ from the double oral auction.

The third process is the secant tâtonnement. In this process the experimenter (price adjuster) announces a price. Agents respond with quantity offers at that price. If excess demand is zero, or if some other stopping rule is involved, the process stops and trade takes place at the announced price. If conditions for stopping are not satisfied, then a new price is announced. Many different formulas for revised price announcements can be imagined. In these experiments the secant process is used.

In the experiments it was common knowledge that price changes follow the formula

$$P_{t+1} = P_t + \left| \frac{P_t - P_{t-1}}{ED_t - ED_{t-1}} \right| ED_t$$

where ED_t is the excess demand at t; i.e., it is the sum of amounts demanded minus the sum of amounts supplied at P_t. Notice that the process is potentially unstable. If excess demand is positive, then prices will increase or if excess demand is negative, prices will decrease. This quality is exactly the unstable behavior that underlies the Walrasian concept.

The process stopped according to two rules.

(1) If excess demand is zero, then the price change is zero and the process stops.

(2) If $\left| \frac{P_t - P_{t-1}}{ED_t - ED_{t-1}} \right|$ is small enough, then a rounding procedure will treat the quantity as zero and the process stops even though excess demand is not zero. This latter property can be important in cases of horizontal demand or supply curves.

2. Participants are trading multiple units. Consequently, extramarginal units can have a strategic use.

Very little is known about the behavior of tâtonnement processes. Operational problems involved with implementing such a process abound. The secant process as opposed to a process often referenced in the literature (i.e., $\dot{X} = \alpha ED$) was chosen as the first to study because natural stopping rules existed in the presence of discontinuities.[3]

IV. MODELS

Two aspects of the economic environment are of interest. The first is the set of equilibria and the second is the detail of the dynamic models. The classical analysis will be maintained throughout the paper. That is, only the market demand and supply functions will be used as the basic parameters of the environment. We will indicate those points where we are aware that this classical model produces results inconsistent with modern game theory.

The Walrasian definition of equilibrium is not the same as the Marshallian definition. Walras defines a price to be an equilibrium if the quantity demanded at that price equals the quantity supplied at that price. Marshall defines a quantity to be in equilibrium if the demand price and supply price are equal at that quantity. Both authors also defined equilibria as limit points of a dynamic process.

Neither author discusses problems caused by discontinuities so latitude remains to apply these theories in ways that appear reasonable. In this -paper an equilibrium is either a point that satisfies a static definition or it is the limit point of a dynamic process.

Table 2 lists the equilibria. The letters correspond to the points as located in Figure 2. Under both demand conditions, D_1 and D_2, the interior points c, d, e are equilibria according to both theories. At the indicated price, quantity demanded equals quantity supplied. Some ambiguity can result if the Marshallian definition of equilibrium, that demand price equals supply price, is used. Strictly speaking, demand price and supply prices are never equal in the environment given the discrete curves as drawn. However, the Marshallian dynamics would "push" the system to the Marshallian stable points in the set $\{c, d, e\}$ if the Marshallian model of dynamics is correct.

The boundary points do not have the symmetry of the interior points. The equilibrium properties of these points change according to the demand conditions and the theory.

In summary, under condition D_1, Marshallian theory would predict equilibration near points $\{c, e\}$ and Walrasian would predict $\{a, d, g\}$. Under conditions D_2 Marshallian theory would predict points $\{b, d\}$ while Walrasian would predict $\{a, c, f\}$. That point a is a Walrasian equilibrium under condition D_1 is a departure from a game theoretic analysis. At prices that high, some producers would be willing to supply even if others produced zero. Thus at prices that high, the support of game theory is lost.

We will now turn to the dynamic models. Since the continuous approximation of the parameters leads to a piecewise linear model, the analysis will be in terms of a linear model. Let the demand equation be

$$X_d - a_d - b_d P_d = 0 \tag{11}$$

3. The proportional rule for adjustment has been studied by Patrick Joyce (1984).

TABLE 2

			Condition D_1		Condition D_2	
Point	Price*	Quantity	Marshall	Walras	Marshall	Walras
a	960	0	non eq.	stable eq.	non eq.	stable eq.
b	630	0	non eq.	non eq.	stable eq.	non eq.
c	500-540	12	stable eq.	unstable eq.	unstable eq.	stable eq.
d	380-410	18	unstable eq.	stable eq.	stable eq.	unstble eq.
e	140-180	30	stable eq.**	unstable eq.	non eq.	non eq.
f	0	28	non eq.	non eq.	non eq.	stable eq.
g	0	30	non eq.	stable eq.	non eq.	non eq.

* Price reflects conditions D_1. Under D_2 the range would be narrower.

** Strictly speaking, this point is not an equilibrium because the demand price is so high. However, quantities on both sides have dynamics that move this direction according to Marshall.

and the supply equation be

$$X_s - a_s - b_s P_s = 0 \tag{12}$$

where X_d and X_s are the demand and supply quantities respectively and when P_d and P_s are the demand price and supply price respectively.

The Marshallian theory of dynamics is

$$X = X_d = X_s$$

$$\frac{dX}{dt} = G(P_d - P_s), \quad G'(\cdot) > 0. \tag{13}$$

The Walrasian theory of dynamics is

$$P = P_s = P_d$$

$$\frac{dP}{dt} = F(X_d - X_s), \quad F'(\cdot) > 0. \tag{14}$$

A problem exists in making these theories operational. The following assumptions will be used:

Assumption 1. The time t refers to an experimental period.

Assumption 2. X_t = the observed number of transactions in period t.

Assumption 3. $X_t = X_d$. That is, the observed number of transactions can be interpreted as X_d in the demand equation (11).

Assumption 4. Disequilibrium movements lie on the demand curve. This means that equation (11) is always satisfied.

Assumption 5. The speeds of adjustment functions $G(\cdot)$ and $F(\cdot)$ in (13) and in (14) are linear. That is $G(P_d - P_s) = \alpha \cdot (P_d - P_s)$ and $F(X_d - X_s) = \beta \cdot (X_d - X_s)$.

Assumptions 1 through 5 together with (11) and (12) yield the following implications of (13) and (14).

Marshallian Theory

$$\frac{dX_t}{dt} = \alpha \psi_{Marshall}(X_t) = \alpha \left[\frac{X_t - a_d}{b_d} - \frac{X_t - a_s}{b_s} \right], \quad \alpha > 0 \tag{15}$$

Walrasian Theory:

$$\frac{dp}{dt} = \frac{1}{b_d} \frac{dX_t}{d_t} = \beta \left[X_t - \left\{ a_s + b_s \left[\frac{X_t - a_d}{b_d} \right] \right\} \right] \tag{16}$$

$$\frac{dX_t}{dt} = \beta\, b_d\, \psi_{Walras}\,(X_t) = \beta b_d \left[X_t - \left\{ a_s + b_s \left[\frac{X_t - a_d}{b_d} \right] \right\} \right], \quad \beta > 0. \tag{17}$$

Under the assumptions listed above and the maintained hypothesis of the theory regarding the market demand and supply, the only unobserved variables in (15) and (17) are the speed of adjustment parameters α and β.

Under the linearity assumption the relationship between the two theories is

$$\left.\frac{dX}{dt}\right|_{Walras} \equiv -\frac{\beta}{\alpha} b_d b_s \left.\frac{dX}{dt}\right|_{Marshall}. \tag{18}$$

Since $b_d b_s > 0$ in the downward sloping case and since $\frac{\beta}{\alpha} > 0$ by the maintained hypotheses of the two theories, the two theories give almost diametrically opposed predictions. The predicted direction of movement will always be the opposite. However, the quantitative relationship can be affected by boundaries and by the nonlinearity of the demand function. Nevertheless, because the functions are piecewise linear the relationship (18) is true for large segments of the price and quantity space.

V. RESEARCH DESIGN

A total of twelve experiments were conducted. Table 3 summarizes the treatment conditions. The first four experiments were double auctions (DA). The first three of these four were conducted under constant demand conditions as single unit double *oral* auctions (DOA). The DOA process required more time than was anticipated. In addition the system was not equilibrating as anticipated so a decision was made to keep demand constant. Since the multiple unit double auction (MUDA) used in experiment 4 is faster,[4] a demand shift was implemented in that market. Near the end of experiments 2 and 4, the location of a Walrasian stable equilibrium was announced. The price was written on the chalkboard and each person was given a number representing the volume of others. We then asked the quantity each would want to trade at the (publicly announced) price if the volume of others was as indicated. The quantities were then collected and summed and the consistency with the hypothetical volume demonstrated. In experiments 8, 11, and 12, trades actually took place and the exercise was called a period. In experiment 4 each individual was told to assume that the volume of all

other individuals was fifteen. The period was then opened. The theoretically predicted volume of eighteen occurred so all participants then knew that profitable trading at that volume was possible.

Experiments 5, 6, 7, and 8 were conducted as sealed bid offer (SBO) auctions. For these, because of the speed of the market we were able to implement the shifting demand design as planned.

4. The MUDA was computerized. The program can be found in Johnson, Lee, Plott (1988).

TABLE 3

Experiment		Market Organization	Demand Conditions
1		DOA	D_1 all 6 periods
2		DOA	D_1 all 10 periods (period 11 deleted—had been preceded by announcement)
3		DOA	D_1 all 10 periods (period 11-12 deleted—had been preceded by announcement)
4	(previously experiment 13)	MUDA	D_1 periods 1-9 D_2 periods 10-24 Announce $P^* = 400$ $X^* = 18$ after period 11, reiterate announcement after period 13.
5		SBO[a]	D_1 periods 1-9 D_2 periods 10-14
6		SBO[b]	D_1 periods 1-9 D_2 periods 10-15
7		SBO[b]	D_1 periods 1-14 D_2 periods 15-20
8		SBO[b]	D_1 periods 1-14 D_2 periods 15-24 Announce $P^* = 400$ $X^* = 18$ after period 20.
9		Tâtonnement	D_1 periods 1-9 D_2 periods 10-13
10		Tâtonnement	D_1 periods 1-9 D_2 periods 10-12
11		Tâtonnement	D_1 periods 1-9 D_2 periods 10-15 Announce $P^* = 400$ $X^* = 18$ after periods 11 and 12.
12		Tâtonnement	D_1 periods 1-9 D_2 periods 10-19 Announce $P^* = 400$ $X^* = 18$ after periods 11 and 12.

a. Public information at the end of a period included the highest bid, lowest bid, lowest accepted bid, and highest accepted ask, price, and volume.

b. The highest rejected bid and lowest rejected ask were announced along with the information described in footnote *a*.

Experiments 9, 10, 11, and 12 were all secant tâtonnement. Demand was held at D_1 for the first nine periods and was shifted to D_2 beginning the tenth period. Demand condition D_2 was maintained for two to four periods after which the experiment terminated or an experimenter intervention occurred. The intervention was in the form of an announcement which demonstrated the existence of the (Marshallian stable) equilibrium at $P^* = 400, X^* = 18$. After such announcements were made, the experiment continued for a few periods.

VI. RESULTS

Figures 3, 4, and 5 contain an example of a time series from each of the three different types of market organization. Table 4 contains the average price and volume for all periods of all experiments. The table indicates when the shift from D_1 to D_2 occurred and when information about equilibria was announced. In the first four experiments under the double auction processes, prices vary within a period so the average price does not contain all of the information. In all other experiments all transactions took place at the same price.

Remark 1. The demand and supply model is not as accurate in the downward sloping supply case as it has been in other studies involving upward sloping supply functions.

In order to understand the remark study the final periods of D_1 for experiments 1, 4, and 10. In these markets volume is about midway between two equilibria and prices are off by 20 percent or more. Usually the accuracy of the competitive model falls within 5 percent or so. The problem is seen again in the volume predictions. In all but two experiments volume was below predictions in the last period of D_1 and it was never above. Thus the errors of the model are systematic and occasionally large.

Conclusion 1. For all experiments under conditions D_1 before the demand shift, prices and volume converge nearer to point c than to any other equilibrium. This point is Marshallian stable and Walrasian unstable.

Again observe the data in the last period of condition D_1. For all experiments the stable Marshallian equilibrium nearest the data is point c and the nearest Walrasion stable equilibrium is point a. All but five of the twenty-four datums are closer to c than to a. The exceptions are prices in experiments 1, 8, 10, and 13 and volume in experiment 10. On average, the price predictions of the (stable) Marshallian model has a 14 percent of price and a 3 unit volume error. By contrast the (stable) Walrasian model exhibits price predictions that are on average off by 20 percent and volume predictions that are off by 9.6 units. The equilibria of the Marshallian stable model are better.

Conclusion 2. For all experiments under conditions D_2 after the demand shift, the data are nearer point b than to any other equilibrium. This point is Marshallian stable and Walrasian unstable.

Consider the final period of condition 2 before any announcements are made about the locations of equilibria. The data are closer to the stable Marshallian equilibrium b than to the stable

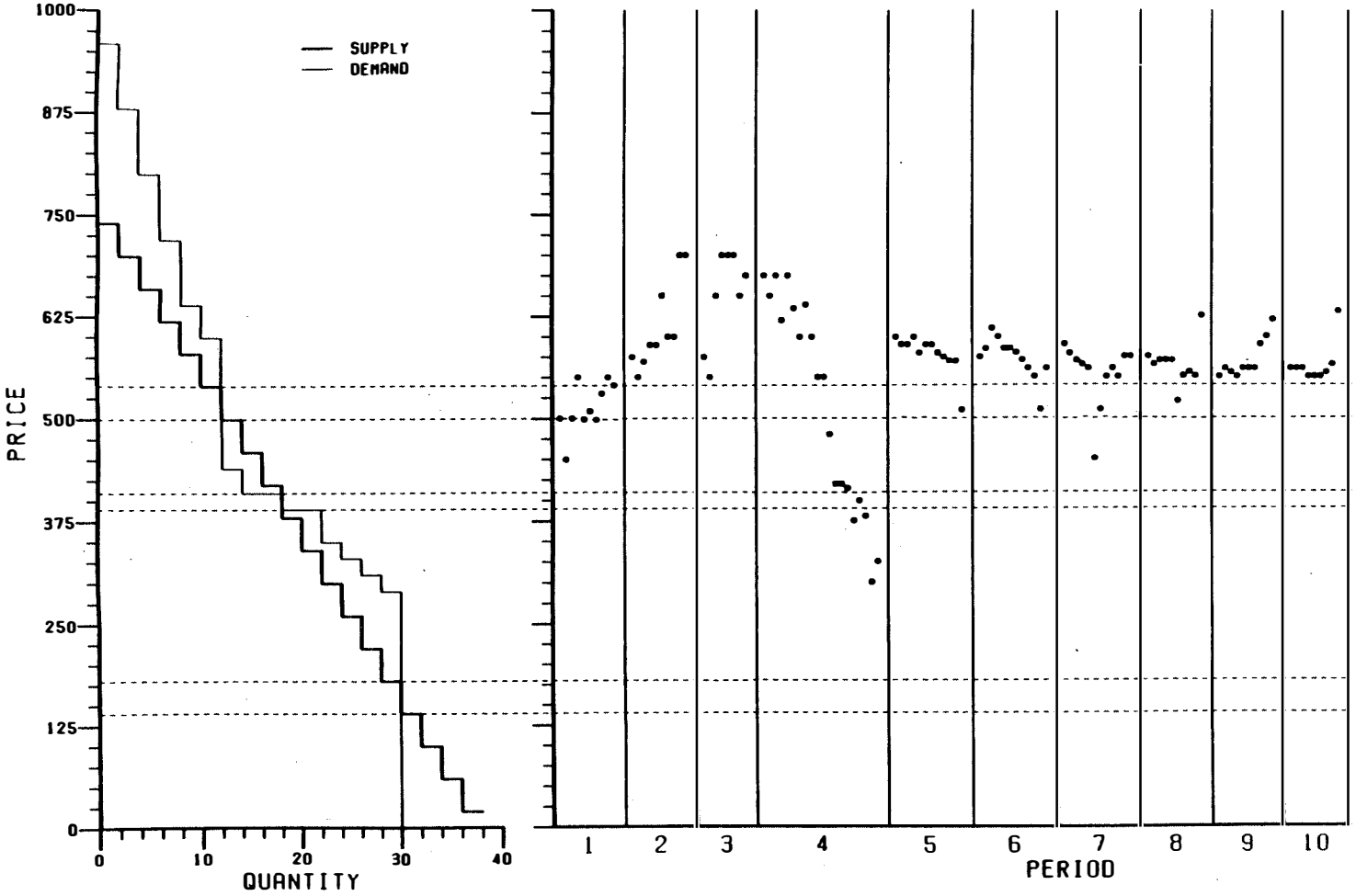

FIGURE 3

All Contracts from Experiment 3, Double Oral Auction

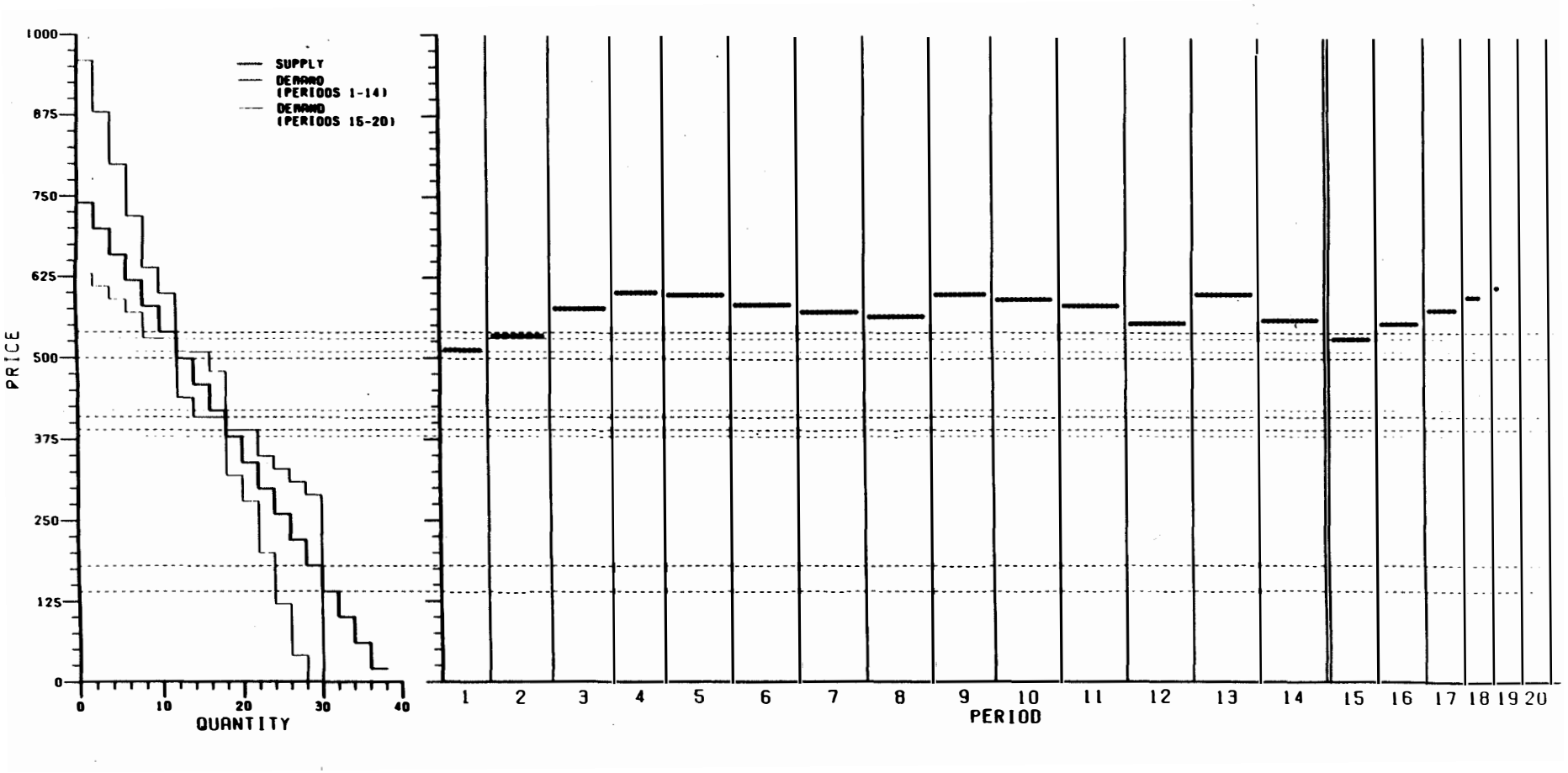

FIGURE 4

All Contracts from Experiment 7, Sealed Bid/Offer

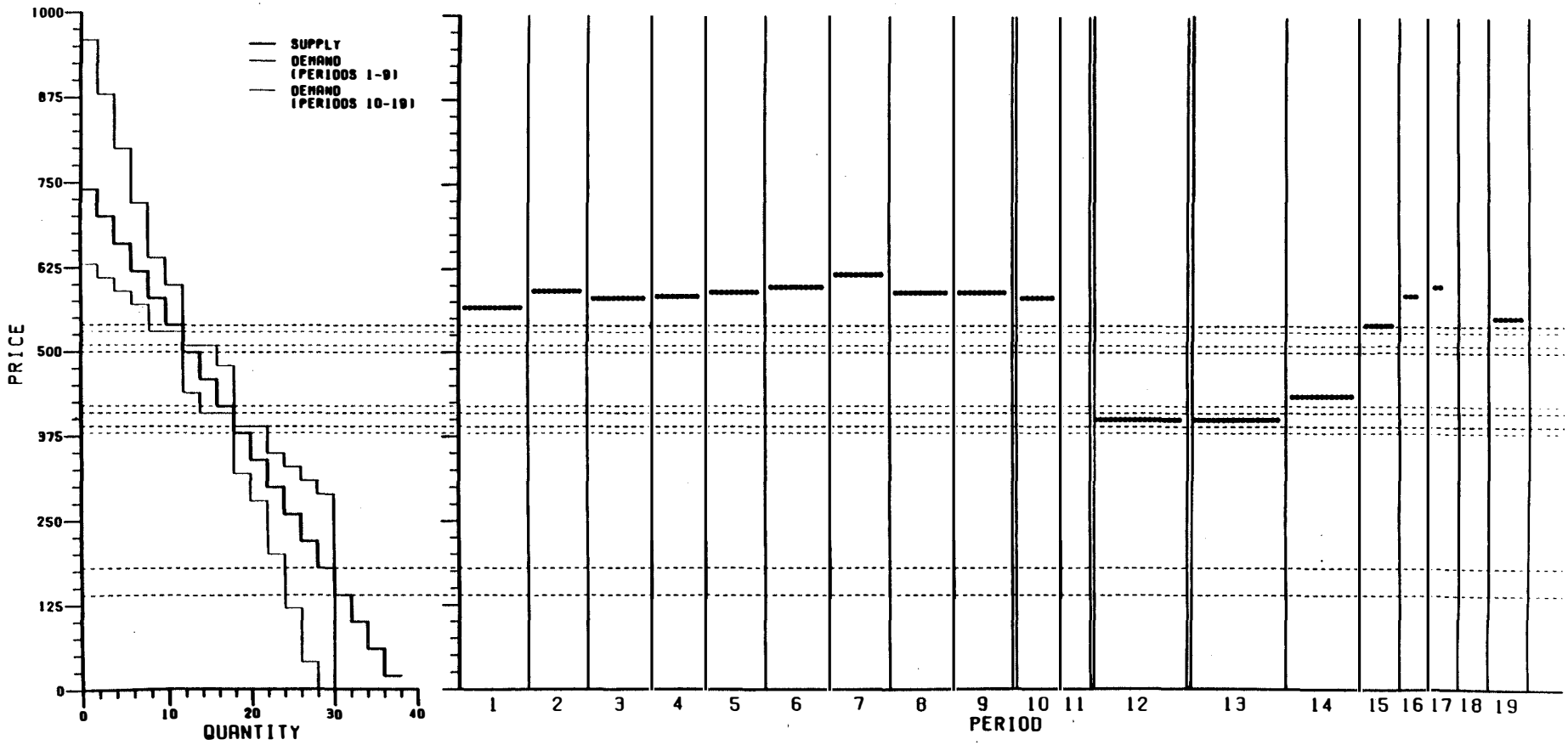

FIGURE 5

All Contracts from Experiment 12, Tâtonnement

TABLE 4

Volume and Average Price for All Periods of All Experiments

Experiment	Period	Vol.	Av. Price
1 DA[a]	1	13	602.3
	2	11	549.4
	3	8	564.5
	4	4	622.5
	5	4	639.8
	6	7	627.9
2 DA	1	10	558.0
	2	12	562.9
	3	9	569.4
	4	12	561.2
	5	12	556.7
	6	12	553.3
	7	11	553.6
	8	12	553.8
	9	13	539.5
	10	12	541.6
3 DA	1	10	513.0
	2	10	612.5
	3	8	650.0
	4	20	519.2
	5	12	578.8
	6	12	572.5
	7	12	552.9
	8	10	565.0
	9	10	570.0
	10	9	564.4
4 MUDA[b]	1	8	627.5
	2	8	632.3
	3	6	631.7
	4	6	633.7
	5	8	648.9
	6	7	646.6
	7	7	649.0
	8	7	653.1
	9	8	659.0
	Treatment Change		
	10	0	
	11	0	
	Treatment Change		
	12	19	456.1
	13	1	450.0
	Treatment Change		
	14	20	403.9
	15	17	419.4
	16	14	438.9
	17	10	455.5
	18	7	467.1
	19	4	500.0
	20	6	450.0
	21	18	461.1
	22	18	452.6
	23	15	464.7
	24	17	472.3
5 SB/O[c]	1	13	440.0
	2	13	440.0
	3	10	500.0
	4	11	600.0
	5	11	600.0
	6	10	610.0
	7	10	609.0
	8	10	599.0
	9	10	599.0
	Treatment Change		
	10	7	560.0
	11	6	585.0
	12	4	594.0
	13	3	600.0
	14	1	600.0

Experiment	Period	Vol.	Av. Price
6 SB/O	1	6	600.0
	2	12	525.0
	3	12	500.0
	4	12	500.0
	5	12	500.0
	6	12	500.0
	7	11	503.0
	8	11	530.0
	9	11	545.0
	Treatment Change		
	10	7	533.0
	11	7	538.0
	12	7	550.0
	13	5	575.0
	14	3	591.0
	15	4	580.0
7 SB/O	1	8	512.0
	2	11	534.0
	3	11	577.0
	4	9	602.0
	5	12	598.0
	6	12	583.0
	7	12	572.0
	8	12	565.0
	9	11	599.0
	10	12	591.0
	11	12	782.0
	12	12	555.0
	13	12	600.0
	14	12	560.0
	Treatment Change		
	15	8	530.0
	16	8	554.0
	17	6	575.0
	18	3	595.0
	19	1	610.0
	20	0	
8 SB/O	1	10	475.0
	2	11	500.0
	3	11	500.0
	4	7	550.0
	5	8	599.0
	6	9	630.0
	7	10	629.0
	8	10	615.0
	9	10	600.0
	10	10	620.0
	11	10	622.0
	12	9	611.0
	13	10	623.0
	14	10	619.0
	Treatment Change		
	15	6	559.0
	16	5	590.0
	17	3	600.0
	18	2	615.0
	19	1	629.0
	20	0	
	Treatment Change		
	21	18	400.0
	22	15	500.0
	23	11	511.0
	24	9	530.0

Experiment	Period	Vol.	Av. Price
9 T[d]	1	8	546.0
	2	10	577.0
	3	9	568.0
	4	10	578.0
	5	10	583.0
	6	12	579.0
	7	10	580.0
	8	11	573.0
	9	10	583.0
	Treatment Change		
	10	3	572.0
	11	3	567.0
	12	1	591.0
	13	3	564.0
10 T	1	12	454.0
	2	12	528.0
	3	6	645.0
	4	8	605.0
	5	9	571.0
	6	9	614.0
	7	6	626.0
	8	5	622.0
	9	5	635.0
	Treatment Change		
	10	1	630.0
	11	1	602.0
	12	0	631.0
11 T	1	8	633.0
	2	9	615.0
	3	10	632.0
	4	10	607.0
	5	10	608.0
	6	10	605.0
	7	9	602.0
	8	10	609.0
	9	11	600.0
	Treatment Change		
	10	2	619.0
	11	0	602.0
	Treatment Change		
	12	18	400.0
	13	18	400.0
	14	17	371.0
	15	18	386.0
12 T	1	12	567.0
	2	10	592.0
	3	11	581.0
	4	9	584.0
	5	10	590.0
	6	11	598.0
	7	10	617.0
	8	11	590.0
	9	10	590.0
	Treatment Change		
	10	7	582.0
	11	0	615.0
	Treatment Change		
	12	18	400.0
	13	18	400.0
	14	13	435.0
	15	6	541.0
	16	3	586.0
	17	2	600.0
	18	0	631.0
	19	6	552.0

a. Double auction
b. Multiple unit double auction.
c. Sealed bid/offer
d. Tâtonnement

Walrasian equilibrium c in seventeen of the eighteen cases. The exception is the price data in experiment 9. On average the price predictions in the stable Marshallian model are off by 3 percent[5] and the quantity predictions are off by 0.9 units. By contrast the price predictions of the stable Walrasian are off by 20 percent on average and the volume predictions is off by 11 units on average.

The Marshallian and Walrasian models are fundamentally theories of dynamics rather than theories of equilibria. Comparison of equilibria does not explore the nature of price movements and thus does not get to the essence of the difference in approach. In order to give a direct test of the two models, discrete variations of (15) and (17) were used. Specifically, the estimated models were

$$\Delta X = X_{t+1} - X_t = a_k + b_k \psi_k(X_t) + \varepsilon_{kt} \tag{19}$$

X_t = observed market volume in period t

$k \in \{Marshall, Walras\}$

$$\psi_{Marshall}(X_t) = (P_d - P_s)\Big|_{X_t} \tag{20}$$

$$\psi_{Walras}(X_t) = (X_d - X_s)\Big|_{X_t} . \tag{21}$$

The values of $\psi_{Marshall}(X_t)$ are observable without additional theory of the adjustment process. The value of $\psi_{Walras}(X_t)$ can be observed as a result of assumptions (1) through (5) as was demonstrated in equation (17). The magnitudes can be estimated by application of equation (19). Both dynamic theories predict

$$a_k = 0$$

$$b_k > 0.$$

However, by virtue of the experimental design it is unlikely to observe $b_k > 0$ for both k since over wide ranges of the variables, the models differ only by a negative constant of proportionality. However, the models are estimated separately because differences can occur in certain areas of the observation space because of the nonlinearities. The models were estimated over several restricted data sets. First all of the data prior to announcements were used. Then, the models were checked using only first period data. The models were also estimated with the inclusion of data after announcements. These perturbations of the data resulted in no changes in the conclusions. The estimates in Table 5 are those for the data before any parameter announcements were made. Since the announcements were not implemented sufficiently systematically to be considered as treatment variables for purposes of statistical analysis, the data after announcements were not used to obtain the regression results reported in Table 5.

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5. These figures assume that the prices are at the Marshallian equilibrium when zero quantity and no prices are observed. This makes the Marshallian model look better but does not change conclusions. In a process like tâtonnement, prices are observed without trade.

TABLE 5

Estimated Coefficients, t-statistic, Durbin-Watson Statistic, and Adjusted R^2

$$\Delta X = a + b\,\psi_k$$

		ψ measured by Marshall				ψ measured by Walras			
	N	$\hat{a}$	$\hat{b}$	DW	R^2	$\hat{a}$	$\hat{b}$	DW	R^2
Double Auction	48	−1.64 (−2.33)	.038 (5.62)	2.03	.459	.623 (.677)	−1.62 (−2.64)	2.14	−.027
Sealed Bid/Offer	69	−.198 (−.73)	.031 (11.12)	P^* = .243	.651	−.198 (−.73)	−12.37 (−.11.12)	P^* = .243	.651
Tâtonnement	47	−1.20 (−2.24)	.034 (7.48)	P^* = .233	.528	−.103 (−.173)	−4.36 (−1.105)	1.754	.004

* An AR(1) was run to correct for autocorrelation.

Conclusion 3. The Walrasian model can be rejected in favor of the Marshallian model in all three organizations.

In Table 5 the estimate of adjustment term, $\hat{b}$, is positive and significant under the Marshallian model. Contrary to the predictions of the Walrasian model, the $\hat{b}$ is always negative and significant except in the tâtonnement where it is not significant. Adjusted R^2 are always better under the Marshallian model. The size of the estimated coefficient, $\hat{b}$, seems small under the Marshallian adjustment theory but in reality the size is simply a result of the units involved in the independent variable, $\psi_{Marshall}(X_t)$. A change of units would change the slope without affecting the intercept.

The support for the Marshallian model is not all positive. Both theories predict that the intercept term will be zero. As shown in Table 5, $\hat{a}_k$ is significantly negative for two of the three processes according to the Marshallian model. However, the magnitudes are small. We conjecture that they result from nonlinearities in the adjustment process or perhaps from the fact that the markets tended to equilibrate with volumes less than the equilibrium.

Figures 6, 7, and 8 contain all regressions. The horizontal axis contains the magnitudes of $\psi_k(\cdot)$ for $k \in \{Marshall, Walras\}$. In the Marshallian case this is the difference between demand price and supply price at the market quantity. In the Walrasian case this is the excess demand implied by the market quantity on the assumption that movement is along the demand curve. The vertical axis measures the change in market quantity that occurred for the next period. As can be seen, the slopes for the Walrasian adjustment model always have the wrong sign. Slopes for the Marshallian model are always positive as predicted by theory.

VII. CONCLUSIONS

This paper explored the two classic theories of stability found in the literature. The stylized results are as follows.

1. The law of supply and demand works with reasonable accuracy. Even though the data fall short of strong support for the model (see Remark 1), the result is surprising because the supply model involved a substantial rational expectations component.

2. Stability seems to be a property of equilibria. Shifts in the demand which cause an equilibrium to become unstable are followed by movement away from the equilibrium.

3. The Marshallian stability model captures the observed phenomena and the Walrasian model does not. Between the two models Marshall is the appropriate one.

4. The conclusions above are independent of market organization. The Marshallian model is the appropriate model even when the market is organized by tâtonnement.

The most important question has not been answered. In terms of modern theory, why does the mechanical adjustment theory advanced by Marshall appear to work? Modern theory has

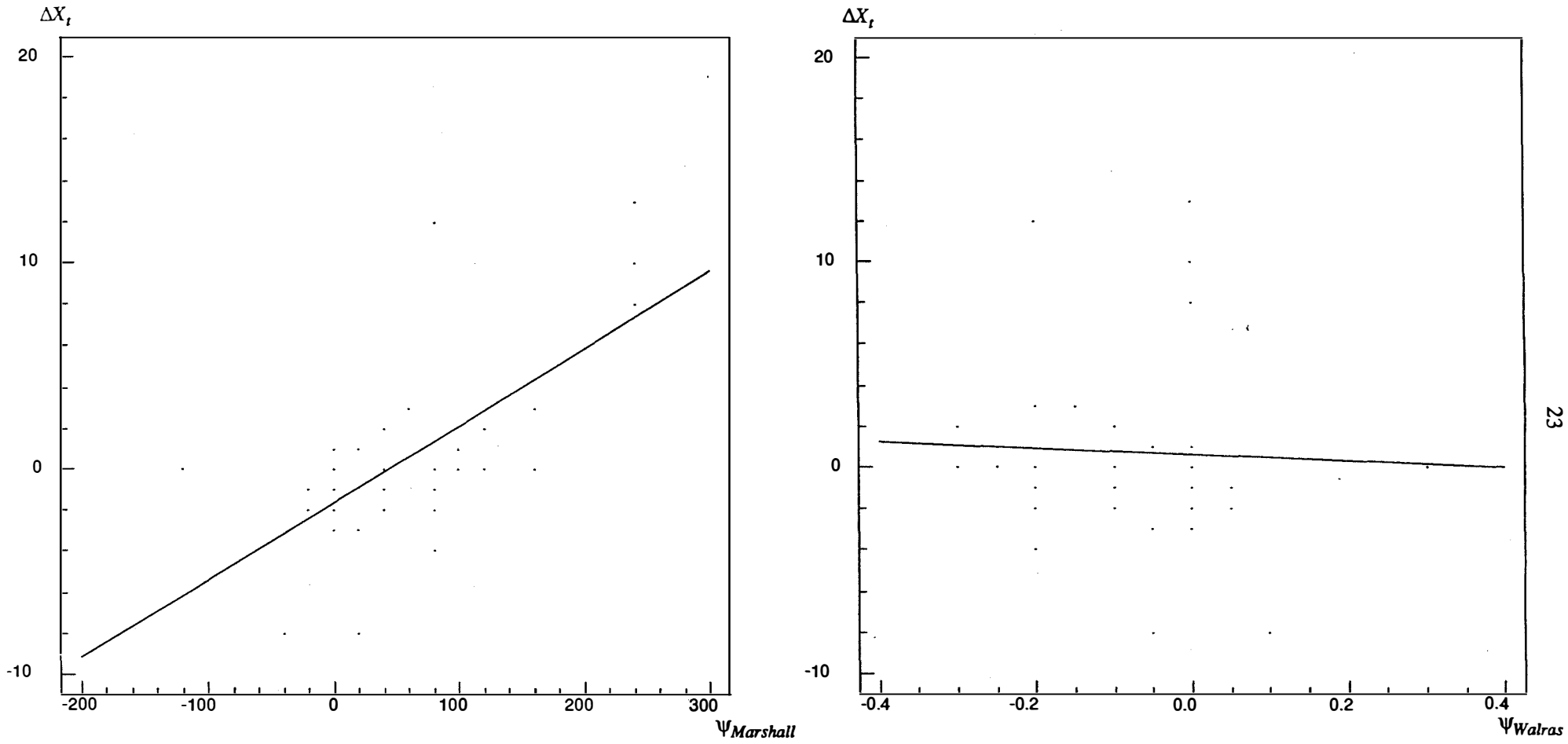

FIGURE 6

$\Delta X_t = \hat{a}_k + \hat{b}_k \Psi_k$

Double Auction

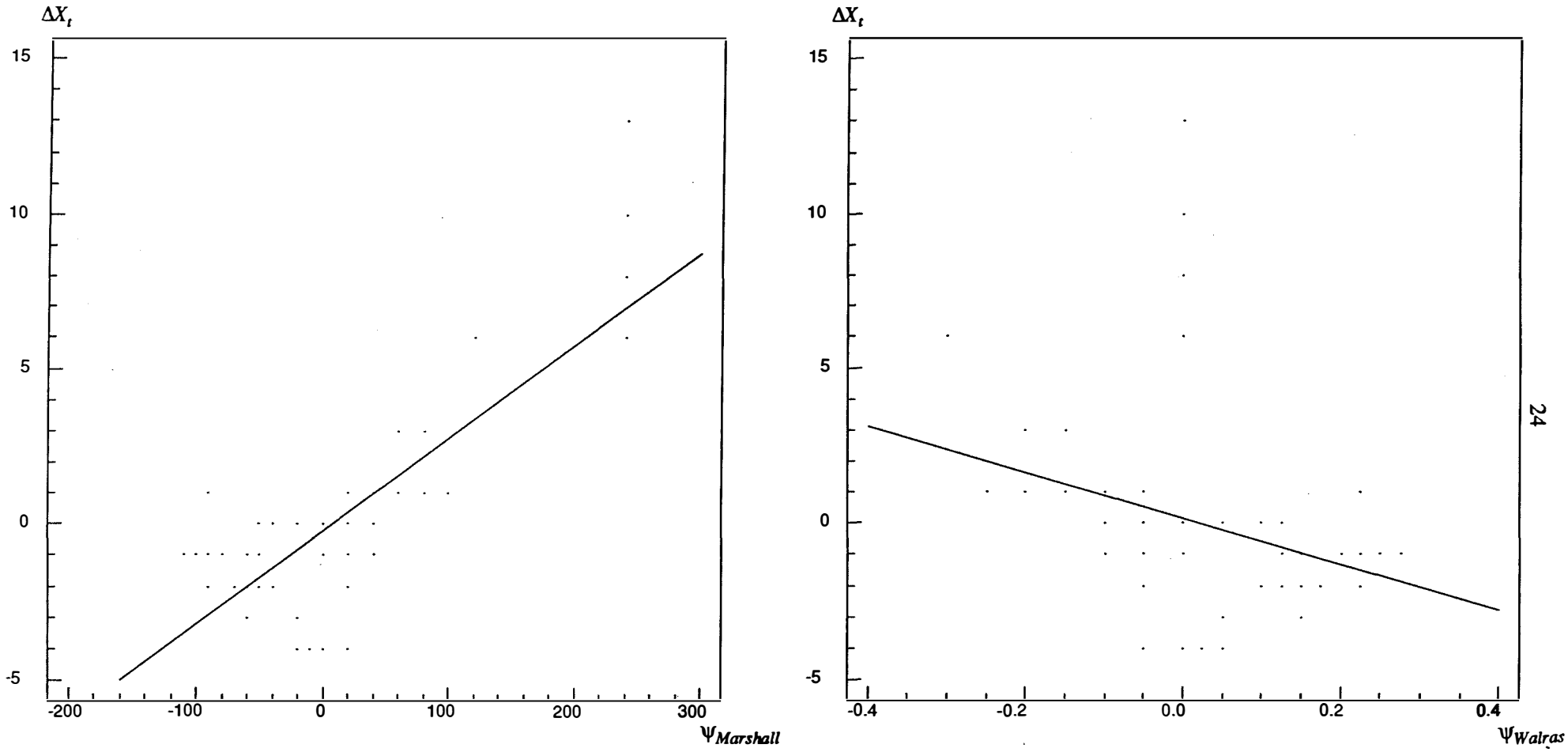

FIGURE 7

$\Delta X_t = \hat{a}_k + \hat{b}_k \Psi_k$

Sealed Bid/Offer

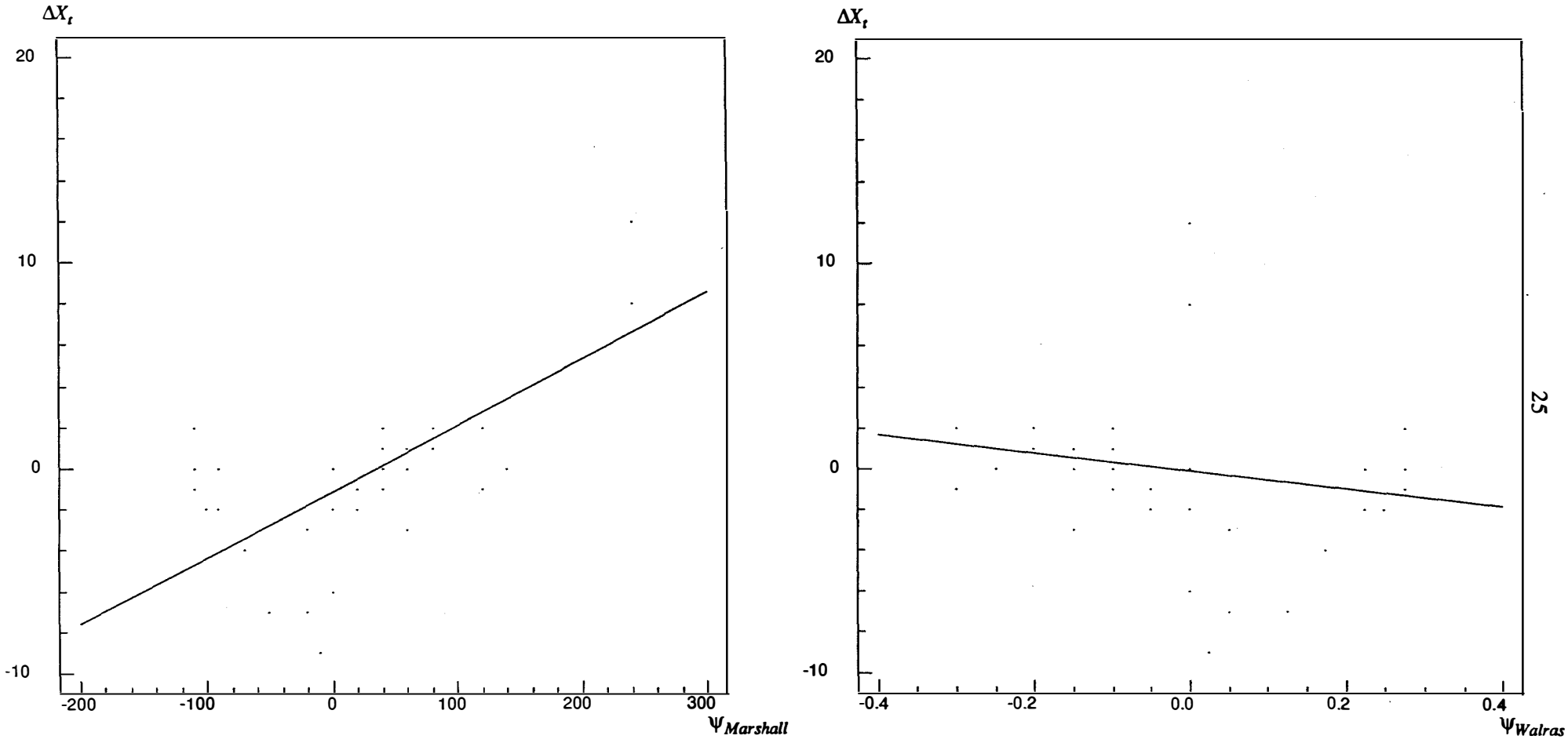

FIGURE 8

$\Delta X_t = \hat{a}_k + \hat{b}_k \Psi_k$

Tâtonnement

advanced far beyond the mechanical idea of demand and supply to focus on the details of individual information processing and strategic behavior. Does the Marshallian model have a firm foundation in modern theory? Or, was it an accident resulting from a choice of parameters and procedures that made the Marshallian model look good? Will the result hold up in the backward bending supply case? The prospect was advanced years ago that the two conditions of supply, forward falling and backward bending, might be characterized by different stability properties.[6]

For some reason the Marshallian concept of stability was dropped from consideration by the profession. The Walrasian model has been almost universally applied. While it is much to early to claim that the practice is wrong, these data suggest that reassessments are in order.

6. I am indebted to Eskander Alvi for calling to my attention Kahn (1933).

APPENDIX

Auctioneer's Introduction

Each of you should now have a folder. Once the folders are opened there should be no talking except to ask me questions and to participate in the market.

You may now open your folders. In each folder there should be a number of pages. The first of these should be labeled "**Buyer No.**" or "**Seller No.**". How many buyers are there? Will all buyers please raise their hands. How many sellers are there? Will all sellers please raise their hands.

I will now read the instructions aloud and you can follow along. I will periodically stop for questions. Please wait until then to ask a question.

You are ***Buyer No.***

In this packet you should find 5 items.

(1) This page.

(2) A set of stapled pages labeled *Instructions*. The last page is labeled *Example (Buyer)*. The numbers used in this example have no relationship to those to be used in the actual market. They are for illustrative purposes only.

(3) A sheet labeled *Record of Purchases and Earnings*, the *Record Sheet*. This sheet is to be used in calculating your profits. The numbers on this sheet are those that will be used in the actual market.

(4) A number of bid submittal forms labeled *Bid Form*. These are to be used for submitting your bids in the market.

(5) A pad of yellow paper which may be used as scrap paper.

You are ***Seller No.***

In this packet you should find 6 items.

(1) This page.

(2) A set of stapled pages labeled ***Instructions***. The last page is labeled ***Example (Seller)***. The numbers used in this example have no relationship to those to be used in the actual market. They are for illustrative purposes only.

(3) A sheet labeled ***Record of Sales and Profits***, the ***Record Sheet***. This sheet is to be used in calculating your profits.

(4) A sheet labeled ***Cost Sheet***. The numbers on this sheet are those that will be used in the actual market.

(5) A number of offer submission forms labeled ***Offer Form***. These are to be used for submitting your offers in the market.

(6) A pad of yellow paper which may be used as scrap paper.

Instructions

General

This is an experiment in the economics of market decision making. Various research foundations have provided funds for this research. The instructions are simple and if you follow them carefully and make good decisions you might earn a considerable amount of money which will be paid to you in cash.

We are going to conduct a market in which some of you will be buyers and some of you will be sellers in a sequence of market days or trading periods. In this packet you will find a sheet, labeled either *Record of Purchases and Earnings* or *Record of Sales and Profits*, which describes the value to you of any decisions you might make. *You are **not** to reveal this information to anyone*. It is your own private information.

The type of currency used in this market is francs. All trading and earnings will be in terms of francs. Each franc is worth _____ dollars to you. *Do **not** reveal this number to anyone*. At the end of the experiment your francs will be converted to dollars at this rate, and you will be paid in dollars. Note that the more francs you earn, the more dollars you earn.

Specific Instructions to Buyers

During each market period you are free to purchase as many units as you might want. For the first unit that you buy ***during a trading period*** you will receive the amount listed in row (1) marked **1^{st} unit redemption value**; if you buy a second unit ***during the same trading period*** you will receive the additional amount listed in row (5) marked **2^{nd} unit redemption value**; etc. The profit from each purchase (which is yours to keep) is computed by taking the difference between the redemption value and purchase price of the unit bought. ***Note that you may not buy a unit for a price which exceeds the redemption value.*** Therefore,

[your profit = (redemption value) - (purchase price)].

Suppose, for example, that you buy two units and that your redemption value for the 1^{st} unit is 6000 and for the 2^{nd} unit is 4500. If you pay 3500 for each unit, your profit is:

profit from 1^{st} unit	=	6000	-	3500	=	2500
profit from 2^{nd} unit	=	4500	-	3500	=	1000
total profit	=	2500	+	1000	=	3500

The blanks on the ***Record Sheet*** will help you record your profit. The purchase price of the 1^{st} unit you buy during the first period should be recorded in row (2). You should then record the profit on this purchase as directed on row (3). Do the same (in the appropriate rows) for any additional units bought in this period. At the end of the period record the total profit in the last row on the page, row (41). Subsequent periods should be recorded similarly in the appropriate column (period 1 in column (1); period 2 in column (2); etc.).

Specific Instructions to Sellers

During each market period you are free to sell as many units as you might be able to. The profit from each sale (which is yours to keep) is computed by taking the difference between the price at which you sold the unit and the cost of the unit. Note that you ***may*** sell a unit at a price below the cost of the unit. Therefore,

[your profit = (sale price) - (cost)].

Your cost depends upon **your volume** and the **volume of others**. This means that when you sell units you will not know your costs with certainty. Your costs will be known only at the end of a period when the total volume of sales is known. Examine your *Cost Sheet*. If the **volume of others** is zero, that is, you were the only one who sold units, then the cost of each of your units is found in the column labeled **0**. If the **volume of others** is 23 then the cost of each of your units is found in the column labeled **23**.

Suppose, for example, that you sold two units in a market in which a total of ten units were sold. Find the appropriate column in your *Example Cost Sheet* (as illustrated on the chalkboard). Since the **volume of others** is 8 units, the cost to you of the 1^{st} unit is 1500 and the cost of the 2^{nd} unit is 2000. If you sold each unit for 3500, your profit is:

profit from 1^{st} unit	=	3500	-	1500	=	2000
profit from 2^{nd} unit	=	3500	-	2000	=	1500
total profit	=	2000	+	1500	=	3500

The blanks on the *Record Sheet* will help you record your profit. The sale price of the 1^{st} unit you sell during the first period should be recorded in row (1). The same should be done (in the appropriate rows) for any additional units sold in this period. At the end of the period, enter the **market volume** of the period in row (A), enter **your volume** in row (B) and subtract row (B) from row (A) to determine the resulting **volume of others** which is entered in row (C). Then look on your *Cost Sheet* to find your unit costs. On the *Record Sheet* enter the cost of the 1^{st} unit in row (2). You should then record the profit on this sale as directed in row (3). After computing the profit for each unit sold, record the total profit for that period in the last row on the page, row (41). Subsequent periods should be recorded similarly in the appropriate column (period 1 in column (1); period 2 in column (2); etc.).

Market Organization (Sealed Bid-Offer Auction)

The market for this commodity is organized as follows: we open the market for a trading period (a trading 'day'). Participants will transact units by submitting bids or offers which may be accepted or rejected. Each participant will decide how many bids or offers to submit by filling out the *Bid Forms* or *Offer Forms* with the buyer or seller number, the period number, and the amount. Under no conditions may a buyer make a bid for a unit that is higher than the redemption value for that unit. Since sellers do not know their costs until the end of the period they may offer any amount for a unit.

Bids and offers are accepted or rejected each period as follows: the *Bid Forms* and *Offer Forms* will be collected from all buyers and sellers. The individual bids will then be ordered from highest bid to lowest bid. Likewise, the individual offers will be ordered from lowest offer to highest offer. The bids and offers are then matched: highest bid to lowest offer, second highest bid to second lowest offer, etc. Each of these matched bids and offers are accepted as long as the amount of the bid is more than the amount of the offer. For example, if there are bids of 3000, 3500, 4000, and 4200 and offers of 2000, 3000, 3300, 3500 they will be matched as follows: bid of 4200 with offer of 2000; bid of 4000 with offer of 3000; bid of 3500 with offer of 3300; and bid of 3000 with offer of 3500. The bids and offers in the first three of these matched sets will be accepted and the remainder will be rejected. Ties will be resolved randomly. After the winning bids and offers have been determined the highest accepted bid, lowest accepted offer, last accepted bid and offer, and first rejected bid and offer will be announced along with the market volume. The bid and offer forms will also be returned with each bid or offer marked "accepted" or "rejected" and the price of the "accepted" bids or offers. Each buyer and seller will then fill in the column on the *Record Sheet* for that period with the prices of his/her accepted bids or offers.

All accepted bids and offers will be transacted at the same price. This price is the average of the maximum of of the ***last accepted offer*** and the ***first rejected bid*** and the minimum of the ***last accepted bid*** and the ***first rejected offer***. In the previous example the price would be 3400 (the maximum of the ***last accepted offer*** and the ***first rejected bid*** is 3300 and the minimum of the ***last accepted bid*** and the ***first rejected offer*** is 3500) as shown on the chalkboard.

Final Observations

1. Trading period 0 will be a trial period to familiarize you with the procedure and will not count toward your cash earnings.

2. Each individual has a large folder. All papers, instructions, records, etc. should be put into this folder. Leave the folder with us before leaving. *Take **nothing** home with you.*

3. We are able to advise you a little on making money. First, you should remember that pennies add up. Over many trades and a long period of time very small amounts earned on individual trades can add up to a great deal of money. Secondly, you should not expect your earnings to be steady. You will have some good periods and some bad periods. During bad times try not to become frustrated. Just stay in there and keep trying to earn what you can. It all adds up in the end.

4. Under no circumstances may you mention anything about activities which might involve you and other participants after the experiment (i.e., no physical threats, deals to split up afterwards, or leading questions).

5. Each individual will be paid in private. Your earnings are strictly your own business.

Period Zero

Auctioneer's Instructions

For period zero I will give an example set of bids and offers. You should record the transactions (accepted bids and offers) corresponding to your seller or buyer number onto your ***Example Record Sheet***. In subsequent periods ***you*** will be submitting the bids and offers and will be recording your transactions on the real ***Record Sheet***.

Period Zero is now open. The ***Bid Forms*** and ***Offer Forms*** have been received from all buyers and sellers and contain the following bids and offers:

Buyer 1 submits bids at 5020, 3000, and 1040.
Buyer 2 submits bids at 4002, 4001, and 1900.
Buyer 3 submits bids at 5500, 3500, and 537.
Buyer 4 submits bids at 5000 and 3510.
Buyer 5 submits bids at 4080.
Buyer 6 submits bids at 4000, 2330, and 168.
Seller 7 submits offers at 3000, 3400, and 4000.
Seller 8 submits offers at 3300, 4450, and 5050.
Seller 9 submits offers at 3330 and 5600.
Seller 10 submits offers at 2710, 3180, and 4250.
Seller 11 submits offers at 2800, 3100, and 4020.
Seller 12 submits offers at 3027 and 3251.

The bids are ordered from highest to lowest and the offers from lowest to highest. The bids are then matched to the offers as follows:

Bids	5500	5020	5000	4080	4002	4001	4000	3510	3500
Offers	2710	2800	3000	3027	3100	3180	3251	3300	3330
Bids	3000	2330	1900	1040	537	168	--		
Offers	3400	4000	4020	4250	4450	5050	5600		

Notice that there is an extra offer which cannot be matched with a bid. Any extra offers or bids are rejected. The first nine (9) matched bids and offers are accepted, the rest are rejected. The price is 3365 (the maximum of the ***last accepted offer*** and the ***first rejected bid*** is 3330 and the minimum of the ***last accepted bid*** and the ***first rejected offer*** is 3400). Were this an actual period all of the ***Bid Forms*** and ***Offer Forms*** would now be returned with the accepted and rejected bids and offers marked along with the price. Also, I would announce that the highest accepted bid was 5500, the lowest accepted offer was 2710, the last accepted bid was 3500, the last accepted offer was 3330, the first rejected bid was 3000, and the first rejected offer was 3400 You should now fill out your ***Example Record Sheets***.

The **market volume** for period zero is 9 units. Sellers should record the **market volume** in row (A), and the number of units that they themselves sold in row (B).

Everyone should now calculate their profit using the forms on the *Example* page.

Buyers should subtract the purchase price of their first unit from the 1^{st} unit redemption value on their *Example Record Sheet*. The same should be done for any additional units purchased.

Sellers should calculate the **volume of others** [row (A) - row (B)] and record this in row (C). They should then examine the column on their *Example Cost Sheet* corresponding to row (C). For some it will be the column numbered **8** and for others it will be the column numbered **7**. Next sellers should write the cost of their 1^{st} unit in row (2) of their *Example Record Sheet* and subtract it from the selling price of their first unit sold to determine their profit on that unit. The same should be done for any additional units sold.

Everyone should also answer the questions at the bottom of the *Example Record Sheet*.

Example (Buyers)

Record of Purchases and Earnings, Buyer No.____

Unit Purchased		Trading Period Number	0	1	2	3	4	5	6	7	8	9	10	11
1	1	1st unit redemption value	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
	2	Purchase price												
	3	Profit (row 1 - row 2)												
	4													
2	5	2nd unit redemption value	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
	6	Purchase price												
	7	Profit (row 5 - row 6)												
	8													
3	9	3rd unit redemption value	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
	10	Purchase price												
	11	Profit (row 9 - row 10)												
	12													
4	13	4th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	14	Purchase price												
	15	Profit (row 13 - row 14)												
	16													
	41	Total per period earnings												

Name_____ Soc. Sec. No._____ Total Payment:_____

Address_____

Calculate your profit for period zero.

If, in period 1, you bought two units for 2000 each, what was your profit for that period?

If, in period 2, you bought one unit for 4000, what was your profit for that period?

What was your total profit for periods 1 and 2?

Example (Sellers)

Cost Sheet

	Volume of Others									
	0	1	2	3	4	5	6	7	8	9
1st unit	7500	6750	6000	5250	4500	3750	3000	2250	1500	750
2nd unit	8000	7250	6500	5750	5000	4250	3500	2750	2000	1250
3rd unit	8500	7750	7000	6250	5500	4750	4000	3250	2500	1750
4th unit	9000	8250	7500	6750	6000	5250	4500	3750	3000	2250

Record of Sales and Profits, Seller No.____

Unit Sold		Trading Period Number	0	1	2	3	4	5	6	7	8	9	10	11
	A	Market volume												
	B	Own volume												
	C	Volume of others (row A - row B)												
1	1	Selling price												
	2	Cost of 1st unit												
	3	Profit (row 1 - row 2)												
	4													
2	5	Selling price												
	6	Cost of 2nd unit												
	7	Profit (row 5 - row 6)												
	8													
3	9	Selling price												
	10	Cost of 3rd unit												
	11	Profit (row 9 - row 10)												
	12													
	41	Total per period												

Name_____ Soc. Sec. No._____ Total Payment_____

Address_____

Calculate your profit for period zero.

If you sold one unit in a market in which five units had been sold before selling your unit, what is the cost of your 2nd unit?

If you sold two units in a market in which no other units had previously been sold, what is the cost of your next unit?

Bid Form

Buyer No. _____ Period _____

Unit	Bid Amount	Accepted/Rejected	Price
1	_____	accepted/rejected	_____
2	_____	accepted/rejected	_____
3	_____	accepted/rejected	_____
4	_____	accepted/rejected	_____
5	_____	accepted/rejected	_____
6	_____	accepted/rejected	_____
7	_____	accepted/rejected	_____
8	_____	accepted/rejected	_____
9	_____	accepted/rejected	_____
10	_____	accepted/rejected	_____

Total Number of Accepted Bids: _____

Offer Form

Seller No. _____ Period _____

Unit	Offer Amount	Accepted/Rejected	Price
1	_____	accepted/rejected	_____
2	_____	accepted/rejected	_____
3	_____	accepted/rejected	_____
4	_____	accepted/rejected	_____
5	_____	accepted/rejected	_____
6	_____	accepted/rejected	_____
7	_____	accepted/rejected	_____
8	_____	accepted/rejected	_____
9	_____	accepted/rejected	_____
10	_____	accepted/rejected	_____

Total Number of Accepted Offers: _____

Market Organization (Oral Double Auction)

The market for this commodity is organized as follows: we open the market for a trading period (a trading 'day'). The period lasts nine (9) minutes. Any buyer (seller) is free at any time during the period to make a verbal bid (offer) to buy (sell) one unit of the commodity at a specified price. The bid (offer) must be higher (lower) than the outstanding bid (offer) should one exist. Any seller (buyer) is free at any time to accept or not accept the bid (offer) of any buyer (seller). If a bid (offer) is accepted a binding contract has been closed for a single unit and the buyer and seller will record the contract price to be included in their profit calculations. Any ties in bids or acceptances will be resolved by a random choice of buyer or seller. Except for the bids (offers) and their acceptance you are not to speak to any other subject. There are likely to be many bids and offers that are not accepted, but you are free to keep trying, and as a buyer or a seller you are free to make as much profit as you can.

Are there any questions?

Final Observations

1. Trading period 0 will be a trial period to familiarize you with the procedure and will not count toward your cash earnings.

2. Each individual has a large folder. All papers, instructions, records, etc. should be put into this folder. Leave the folder with us before leaving. *Take* ***nothing*** *home with you.*

3. We are able to advise you a little on making money. First, you should remember that pennies add up. Over many trades and a long period of time very small amounts earned on individual trades can add up to a great deal of money. Secondly, you should not expect your earnings to be steady. You will have some good periods and some bad periods. During bad times try not to become frustrated. Just stay in there and keep trying to earn what you can. It all adds up in the end.

Some people rush to trade. Others find it advantageous to "shop" or spread their trading over the period. We are unaware of any particular "best" strategies and suggest that you adapt accordingly.

The record sheets sometimes lead people to think an advantage exists in recording units in some sequence other than the actual sequence in which they were bought or sold. Consider a buyer with the first two redemption values at 6000 and 4500 respectively. The buyer purchases a first unit at 3500 and a second becomes available at 5000. Only the first will be purchased and the total profit would be 2500. Suppose, however, that the 3500 priced unit is recorded with the 4500 (2^{nd} unit) redemption value for a profit of 1000. Then the 5000 priced unit can be purchased and recorded with the 6000 (1^{st} unit) redemption value for a profit of 1000. Notice that the total profit is now only 2000.

Consider a seller with costs for the first two units of 3000 and 3500 respectively (**volume of others** is 6 in this example). The seller sells a first unit at 3900 and the opportunity arises to sell a second at 3400. Only the first will be sold and the total profit would be 900. Suppose, however, that the 3900 priced unit is recorded with the 3500 (2^{nd} unit) cost for a profit of 400. Then the 3400 priced unit can be sold and recorded with the 3000 (1^{st} unit) cost for a profit of 400. Notice that the total profit is now only 800.

4. Under no circumstances may you mention anything about activities which might involve you and other participants after the experiment (i.e., no physical threats, deals to split up afterwards, or leading questions).

5. Each individual will be paid in private. Your earnings are strictly your own business.

6. Buyers tender bids verbally by indicating in sequence "(buyer number) **BIDS** (amount)" or, if sellers tender offers, the sequence is "(seller number) **OFFERS** (amount)."

Period Zero

Auctioneer's Instructions

For period zero I will do both the part of the buyers and sellers, although you will be recording the transactions corresponding to your role onto your *Example Record Sheet*.

In subsequent periods *you* will be doing the buying and the selling and will be recording your transactions on the real *Record Sheet*.

Period Zero is now open.
Buyer 1 bids at 1500.
Seller 7 offers at 6000.
Buyer 2 bids at 2500.
Buyer 2's bid cancels Buyer 1's bid and is the only outstanding bid. Notice that Buyer 2's bid is higher than Buyer 1's. In order for a bid to be admissible it must be an improvement over the outstanding bid.
Buyer 4 bids at 3000.
Seller 7 offers at 4500.
Seller 7's offer is an improvement over the outstanding offer of Seller 10 and automatically cancels Seller 10's offer.
Buyer 1 bids at 4400.
Seller 10 accepts Buyer 1's bid at 4400.
Buyer 1 and Seller 10 have a contract at 4400.
This is an example of a contract. Buyer 1 has purchased his/her first unit and Seller 10 has sold his/her first unit. Both are now working on their second units. Everyone else is still working on their first units. The market is open for any bids and offers.

Assume that the following additional contracts are also made during period zero:
Seller 9 and Buyer 6 at 5000.
Seller 7 and Buyer 5 at 3770.
Seller 10 and Buyer 3 at 4000.
Seller 11 and Buyer 4 at 3890.
Seller 12 and Buyer 2 at 4505.
Seller 7 and Buyer 4 at 3500.
Seller 11 and Buyer 1 at 3655.
Seller 8 and Buyer 5 at 3000.

The **market volume** for period zero is 9 units. Sellers record the **market volume** in row (A), and the number of units that they sold themselves in row (B).

Calculate your profit using the forms on the *Example* page.
Buyers should subtract their purchase price from their first unit redemption value on the *Example Record Sheet* and do the same for any subsequent units purchased.

Sellers should calculate the **volume of others** [row (A) - row (B)] and record this in row (C). They should then examine the column on their *Example Cost Sheet* corresponding to row (C). For some it will be the column numbered **6** and for others it will be the column numbered **7**. Now write the cost of the first unit in row (2) of the *Example Record Sheet* and subtract it from the selling price to determine your profit on that unit. Do the same for any additional units.

Record of Purchases and Earnings, Buyer No. 1,6

Unit Purchased		Trading Period Number	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1st unit redemption value	960	960	960	960	960	960	960	960	960	590	590	590
	2	Purchase price												
	3	Profit (row 1 - row 2)												
	4													
2	5	2nd unit redemption value	600	600	600	600	600	600	600	600	600	570	570	570
	6	Purchase price												
	7	Profit (row 5 - row 6)												
	8													
3	9	3rd unit redemption value	440	440	440	440	440	440	440	440	440	480	480	460
	10	Purchase price												
	11	Profit (row 9 - row 10)												
	12													
4	13	4th unit redemption value	350	350	350	350	350	350	350	350	350	200	200	200
	14	Purchase price												
	15	Profit (row 13 - row 14)												
	16													
5	17	5th unit redemption value	330	330	330	330	330	330	330	330	330	120	120	120
	18	Purchase price												
	19	Profit (row 17 - row 18)												
	20													
6	21	6th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	22	Purchase price												
	23	Profit (row 21 - row 22)												
	24													
7	25	7th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	26	Purchase price												
	27	Profit (row 25 - row 26)												
	28													
8	29	8th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	30	Purchase price												
	31	Profit (row 29 - row 30)												
	32													
9	33	9th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	34	Purchase price												
	35	Profit (row 33 - row 34)												
	36													
10	37	10th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	38	Purchase price												
	39	Profit (row 37 - row 38)												
	40													
	41	Total per period earnings												

Name _____ Soc. Sec. No. _____ Total Payment _____

Address _____

Unit Purchased		Trading Period Number	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1st unit redemption value	880	880	880	880	880	880	880	880	880	610	610	610
	2	Purchase price												
	1	Profit (row 1 - row 2)												
	4													
2	5	2nd unit redemption value	640	640	640	640	640	640	640	640	640	530	530	530
	6	Purchase price												
	7	Profit (row 5 - row 6)												
	8													
3	9	3rd unit redemption value	410	410	410	410	410	410	410	410	410	510	510	510
	10	Purchase price												
	11	Profit (row 9 - row 10)												
	12													
4	13	4th unit redemption value	390	390	390	390	390	390	390	390	390	280	280	280
	14	Purchase price												
	15	Profit (row 13 - row 14)												
	16													
5	17	5th unit redemption value	310	310	310	310	310	310	310	310	310	40	40	40
	18	Purchase price												
	19	Profit (row 17 - row 18)												
	20													
6	21	6th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	22	Purchase price												
	23	Profit (row 21 - row 22)												
	24													
7	25	7th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	26	Purchase price												
	27	Profit (row 25 - row 26)												
	28													
8	29	8th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	30	Purchase price												
	31	Profit (row 29 - row 30)												
	32													
9	33	9th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	34	Purchase price												
	35	Profit (row 33 - row 34)												
	36													
10	37	10th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	38	Purchase price												
	39	Profit (row 37 - row 38)												
	40													
	41	Total per period earnings												

Name _____ Soc. Sec. No. _____ Total Payment _____

Address _____

3,4

Unit Purchased		Trading Period Number	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1st unit redemption value	800	800	800	800	800	800	800	800	800	630	630	630
	2	Purchase price												
	3	Profit (row 1 - row 2)												
	4													
2	5	2nd unit redemption value	720	720	720	720	720	720	720	720	720	530	530	530
	6	Purchase price												
	7	Profit (row 5 - row 6)												
	8													
3	9	3rd unit redemption value	410	410	410	410	410	410	410	410	410	510	510	510
	10	Purchase price												
	11	Profit (row 9 - row 10)												
	12													
4	13	4th unit redemption value	390	390	390	390	390	390	390	390	390	320	320	320
	14	Purchase price												
	15	Profit (row 13 - row 14)												
	16													
5	17	5th unit redemption value	290	290	290	290	290	290	290	290	290	0	0	0
	18	Purchase price												
	19	Profit (row 17 - row 18)												
	20													
6	21	6th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	22	Purchase price												
	23	Profit (row 21 - row 22)												
	24													
7	25	7th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	26	Purchase price												
	27	Profit (row 25 - row 26)												
	28													
8	29	8th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	30	Purchase price												
	31	Profit (row 29 - row 30)												
	32													
9	33	9th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	34	Purchase price												
	35	Profit (row 33 - row 34)												
	36													
10	37	10th unit redemption value	0	0	0	0	0	0	0	0	0	0	0	0
	38	Purchase price												
	39	Profit (row 37 - row 38)												
	40													
	41	Total per period earnings												

Name_____ Soc. Sec. No._____ Total Payment_____

Address_____

Record of Sales and Profits, Seller No. _____

Unit Sold		Trading Period Number	1	2	3	4	5	6	7	8	9	10	11	12
	A	Market volume												
	B	Own volume												
	C	Volume of others (row A - row B)												
1	1	Selling price												
	2	Cost of 1st unit												
	3	Profit (row 1 - row 2)												
	4													
2	5	Selling price												
	6	Cost of 2nd unit												
	7	Profit (row 5 - row 6)												
	8													
3	9	Selling price												
	10	Cost of 3rd unit												
	11	Profit (row 9 - row 10)												
	12													
4	13	Selling price												
	14	Cost of 4th unit												
	15	Profit (row 13 - row 14)												
	16													
5	17	Selling price												
	18	Cost of 5th unit												
	19	Profit (row 17 - row 18)												
	20													
6	21	Selling price												
	22	Cost of 6th unit												
	23	Profit (row 21 - row 22)												
	24													
7	25	Selling price												
	26	Cost of 7th unit												
	27	Profit (row 25 - row 26)												
	28													
8	29	Selling price												
	30	Cost of 8th unit												
	31	Profit (row 29 - row 30)												
	32													
9	33	Selling price												
	34	Cost of 9th unit												
	35	Profit (row 33 - row 34)												
	36													
	41	Total per period												

Name _____ Soc. Sec. No. _____ Total Payment _____

Address _____

Cost Sheet

Seller # 7, 9

	Volume of Others																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1st unit	760	700	670	640	610	580	500	470	440	410	380	300	270	240	210	180	100	70	40	20	20	20	20	20	20	20	20	20	20	20	20	20	20
2nd unit	860	780	750	720	690	660	580	550	520	490	460	380	350	320	290	260	180	150	120	90	60	20	20	20	20	20	20	20	20	20	20	20	20
3rd unit	940	860	830	800	770	740	660	630	600	570	540	460	430	400	370	340	260	230	200	170	140	60	30	20	20	20	20	20	20	20	20	20	20
4th unit	1020	940	910	880	850	820	740	710	680	650	620	540	510	480	450	420	340	310	280	250	220	140	110	80	50	20	20	20	20	20	20	20	20
5th unit	1100	1020	990	960	930	900	820	790	760	730	700	620	590	560	530	500	420	390	360	330	300	220	190	160	130	100	20	20	20	20	20	20	20
6th unit	1160	1100	1070	1040	1010	980	900	870	840	810	780	700	670	640	610	580	500	470	440	410	380	300	270	240	210	180	100	70	40	20	20	20	20
7th unit	1260	1160	1150	1120	1090	1060	980	950	920	890	860	780	750	720	690	660	580	550	520	490	460	380	350	320	290	260	180	150	120	90	60	20	20
8th unit	1340	1280	1230	1200	1170	1140	1060	1030	1000	970	940	860	830	800	770	740	660	630	600	570	540	460	430	400	370	340	260	230	200	170	140	60	30

Cost Sheet

Seller # 8, 10

	Volume of Others																														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1st unit	820	790	760	730	700	620	590	560	530	500	420	390	360	330	300	220	190	160	130	100	20	20	20	20	20	20	20	20	20	20	20	20	20
2nd unit	900	870	840	810	780	700	670	640	610	580	500	470	440	410	380	300	270	240	210	180	100	70	40	20	20	20	20	20	20	20	20	20	20
3rd unit	980	950	920	890	860	780	750	720	690	660	580	550	520	490	460	380	350	320	290	260	180	150	120	90	60	20	20	20	20	20	20	20	20
4th unit	1060	1030	1000	970	940	860	830	800	770	740	660	630	600	570	540	460	430	400	370	340	260	230	200	170	140	60	30	20	20	20	20	20	20
5th unit	1140	1110	1080	1050	1020	940	910	880	850	820	740	710	680	650	620	540	510	480	450	420	340	310	280	250	220	140	110	80	50	20	20	20	20
6th unit	1220	1190	1160	1130	1100	1020	990	960	930	900	820	790	760	730	700	620	590	560	530	500	420	390	360	330	300	220	190	160	130	100	20	20	20
7th unit	1300	1270	1240	1210	1180	1100	1070	1040	1010	980	900	870	840	810	780	700	670	640	610	580	500	470	440	410	380	300	270	240	210	180	100	70	40
8th unit	1380	1350	1320	1290	1260	1180	1150	1120	1090	1060	980	950	920	890	860	780	750	720	690	660	580	550	520	490	460	380	350	320	290	260	180	150	120

Cost Sheet

Seller # 11, 12

	Volume of Others																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1st unit	800	770	740	680	630	600	570	540	480	430	400	370	340	280	230	200	170	140	80	30	20	20	20	20	20	20	20	20	20	20	20	20	20
2nd unit	880	850	820	740	710	680	650	620	540	510	480	450	420	340	310	280	250	220	140	110	80	80	20	20	20	20	20	20	20	20	20	20	20
3rd unit	960	930	900	820	790	760	730	700	620	590	560	530	500	420	390	360	330	300	220	190	160	130	100	20	20	20	20	20	20	20	20	20	20
4th unit	1040	1010	980	900	870	840	810	780	700	670	640	610	580	500	470	440	410	380	300	270	240	210	180	100	70	40	20	20	20	20	20	20	20
5th unit	1120	1090	1060	980	950	920	890	860	780	750	720	690	660	580	550	520	490	460	380	350	320	290	260	180	150	120	90	60	20	20	20	20	20
6th unit	1200	1170	1140	1060	1030	1000	970	940	860	830	800	770	740	660	630	600	570	540	460	430	400	370	340	260	230	200	170	140	60	30	20	20	20
7th unit	1280	1250	1220	1140	1110	1080	1050	1020	940	910	880	850	820	740	710	680	650	620	540	510	480	450	420	340	310	280	250	220	140	110	80	50	20
8th unit	1360	1330	1300	1220	1190	1160	1130	1100	1020	990	960	930	900	820	790	760	730	700	620	590	560	530	500	420	390	360	330	300	220	190	160	130	100

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